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The integration of planted and natural forests in a regional landscape

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Abstract. The 10,700 km^2 region of northwestern Oregon, USA, is dominated by mountainous forested landscapes fringed by agricultural lands and rapidly expanding urban areas. The Douglas-fir/western-hemlock trees, admixed with other species, in the mild, moist regional climate with rich soils are among the most highly productive of temperate forests. Timber harvest has been the dominant land use for much of this century. Many current forest stands are planted, and have the potentials to be managed and shaped for a variety of traditional and evolving forestry objectives. The ages, resilience and productivity of these forests and mosaics of land ownerships permit a variety of future scenarios of forested landscapes, constrained largely by capacities of social organizations to plan and execute management for desired future conditions.

Introduction

Northwest Oregon is a landscape of forests that blanket coastal mountains from the farmlands and expanding urban areas on the east to the Pacific Coast on the west. Planted forests are a major component of this forested landscape: the 147,307 ha (364,000 A) Tillamook State Forest stands as a tribute to human planting efforts to rejuvenate a landscape impacted by fires in 1933, 1939, 1945 and 1951; extensive corporate and state forest lands extend to the north, and private and Federal forests to the south; planted pines stabilize dunes that frame the Pacific Coast; hybrid cottonwoods line the banks of the Columbia River and intermingle with farmlands and Christmas tree farms on the fringes of the Willamette Valley. The complex mosaics of planted forests among natural forest stands and human-created land patterns are products of sculpting by successive generations of people interacting with bio-physical forces. The variety, nature and significance of these planted and natural forests and tree farms create a complex web of interdependencies that chal-

lenge the rhetoric of sustainability: How to maintain ecological, economic and social "balance" in the face of dynamic demographics, technologies, knowledge and ecological forces in a regional, forested landscape?

The landscape that is the subject of this paper is the Northwest corner in the State of Oregon, encompassing Clatsop, Columbia, Washington, Tillamook and Yamhill counties, an area of 1,069,677 ha (4130 mi^2; 10,696.7 km^2). We chose this area as an example because of the dominance of forests on the landscape along with a socio-cultural and economic gradient. The forests of the Coast Range, which rises from sea level to 1220 m (0–4,000 ft), dominate the land. Even on the mountain tops, there are few rocky promontories in this forested sea of green. In the absence of development, the western forested slopes meet the sea with only a narrow band of sand or steep rocky cliffs separating the waves and trees. To the east, this region is bounded by the Willamette Valley and urban Portland. The north boundary is defined by the Columbia River, along the Oregon – Washington border, and to the south the area of interest is arbitrarily halted at the Lincoln and Polk county borders.

Regional biological and physical forces

Parent materials for the soils in the Oregon Coast range are dominated by sandstones and siltstones, interspersed with numerous areas of basaltic and other volcanic materials. The soils are heavily weathered and although susceptible to landslides, many are deep, nutrient-rich and well-drained making them highly suitable for forest growth. The slopes of the coastal mountains range from gentle rolling to steep and rocky with few flat valleys or benches. The terrain is highly dissected by streams and rivers that are noted for their rapid increases in peak flow rates during winter storms, and are highly valued as habitats for numerous anadramous fish populations.

The Pacific Ocean exerts a strong influence over the climate. The majority of the area is characterized by relatively warm winters, cool summers and high rainfall. Even higher elevations are too warm to maintain a snowpack throughout the winter. Annual rainfall amounts range from 1000 to 3200 mm, with up to 5000 mm on local mountain tops. High winds dominate the physical forces exerted by the climate, particularly along the ocean slopes. This combination of a cool, wet, yet moderate, climate is the dominant reason for the extreme productivity and unique vegetation of the region, some of the most productive temperate forests of the world (Grier et al. 1989; Waring and Franklin 1979).

Coastal rainforests have dominated this landscape for over 2 million years. Maintenance of diversity and adaptation of the resident species over evolutionary time has resulted in an extremely productive ecosystem that is well

adapted to the climate and natural disturbances associated with it (Waring and Franklin 1979). Currently, in northern Clatsop county, primary succession is still occurring on sand recently deposited along the mouth of the Columbia River. Initial invasion is by various beach grass species in conjunction with shore pine (*Pinus contorta var.contorta* Dougl. ex. Loud.). As the pines shade out the grass, sword fern (*Polystichum munitum*) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.) emerge completing the transition toward a coastal forest ecosystem.

Years of evolutionary change in concert with the unique climatic features have resulted in tremendous accumulations of biomass (Waring and Franklin 1979). The tree-generated biomass that occurs is dominated by relatively few species of conifers. Four major conifer species; Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western red cedar (*Thuja plicata* Donn ex D. Don), and Sitka spruce account for approximately 90% of the conifer biomass. The remainder is composed of grand fir, (*Abies grandis* (Dougl. exD. Don) Lindl.), noble fir (*Abies procera* Rehd.), Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) shore pine, and Pacific yew, (*Taxus brevifolia* Nutt.). Deciduous species, about 15% of the total tree biomass, are dominated by red alder (*Alnus rubra* Bong.) and big leaf maple (*Acer macrocarpa* Pursh). The overwhelming dominance of conifer species is unusual compared to coastal forest regions of the world at similar latitudes that have either mixed or largely deciduous forest types.

The very favorable growing conditions for plants result in a high degree of inter and intra species competition for growing space and light. Therefore, the selective pressures have been for large, long-lived individuals that are able to outcompete and outlive invading vegetation. Of the conifer species that occur here, the oldest and largest representatives have historically been located in this region. Publications and vegetative surveys from as early as 1908 state that many of the largest individuals had been felled, so it is hard to predict what the largest potential size for many of these species really is (Sudworth 1908). Estimates of maximum ages for western red cedar exceed 1400 years. (Pojar and MacKinnon 1996). Sitka spruce is thought to have a maximum diameter of 525 cm and 95 meters in height. (Pojar and MacKinnon 1996) Currently the *average* projected tree height in this region at 100 years of age is 55 meters (Pojar and MacKinnon 1996). Aside from the large diameter and extreme height the density of stems per hectare or basal area is very high, often exceeding 77 sq. meters per hectare (300 sq. ft per acre) (Burns and Honkala 1990).

Fire and wind have been the most prevalent landscape-scale disturbance mechanisms influencing forest succession in this four county region, while

landslides and flooding regularly disturb small to medium areas of tens to hundreds of square hectares, with occasional "catastrophic" events affecting tens of square kilometers. The slopes facing the ocean are periodically battered by high winds often exceeding 130 km/hr (80 mph). Occasionally, hurricane force winds in excess of 160 km/hr (100 mph) sweep across the headlands into the interior, causing tree blowdown, particularly along ridges, shoulders of hills and unprotected areas. The interior Coast Range and valley slopes have been subject to infrequent but catastrophic fires ignited by lightning and more recently, human-caused. In contrast, riparian areas are subject to frequent disturbance from debris flows, slope failure and high stream flow generated by the perennially high winter rainfall and unstable soils.

Pathogenic organisms did not leave their mark through the historical record so it is difficult to predict their impact in evolutionary times. In more recent history, there have been a number of pathogens identified with these forests. Gap level disturbances are associated with several root rot pathogens that are common in the region. Outbreaks of hemlock looper (*Lambdina fiscella lugubruso* (Hurst.), a defoliating insect on hemlock, have been noted several times in the past 100 years but long-term historical records are not as clear. Douglas-fir bark beetle (*Dendroctonus pseudotsugae*) and Sitka spruce tip-weevil (*Pissodes strobi* (Pk.)) have historically been present as well. Within the past ten years, Swiss needle cast (*Phaeocryptopus gaeumannii*), a needle pathogen on Douglas-fir has been severely impacting Douglas-fir on the western edge of the region. Overall the area is relatively free of major mortality-causing insect and pathogenic diseases that generally play such an important role in the elimination of early seral species in many forested ecosystems.

The origins of the forests found here at the time of first human settlements, in about 6000 BC, were products of dynamics of vegetation advances and retreat to and from refugia during Pleistocene ice ages and subsequent climate fluctuations. Followed by cycles of more minor disturbances and secondary succession. The infrequent fire, interspersed with frequent windstorm, landslides, floods and pathogenic disturbances created a mosaic of species, age classes and patch sizes across the landscape.

Human influences on forest structure-the recent past

The forests we currently view in this landscape are a result of human influence interacting with ecosystem response to disturbance. Well before the arrival of Europeans, the Native Americans of the region shaped and modified the landscape in ways to sustain and support their way of life. Fire was their principal management tool and it led to changes in the nature of the species,

their predominance, and their distribution. Indeed, many observers conclude that our lack of understanding of the profound influence of Native Americans on the regional landscape continues to plague our ability to understand natural historic conditions.

With the arrival of European settlers in the 1800s, the pace of change in the bio-physical character of the region quickened. Ironically, the forests of the region were the source of both anxiety as well as wealth. For many, the vast, sprawling forests were a source of threat, both in terms of personal safety as well as a spiritual reminder of the fragile hold civilization held on the wilderness. As settlers explored accessible valleys, surrounding forests were cleared and burned to make room for crops and pastures. Tree felling, burning, stump removal, plowing and sowing increased. Fire, set to clear lowlands, often spread into undisturbed forested uplands resulting in catastrophic fires which reburned some areas more often than historic frequencies.

This "land taming" was a legacy of centuries of attitudes, buttressed by religious edicts, that pressed for the subjugation of the wilderness and its conversion to civilization. At the same time, these forests were the source of wealth and the foundation of the region's development. Taken together, and further abetted by government policies and programs designed to facilitate the economic development of the region, the vast forests were rapidly exploited by early settlers and increasingly large proportions of the region changed from public domain to private ownership.

The majority of early settlement and logging occurred close to the rivers which supplied log transport and power to run the mills. By 1850, there were active lumber producing operations located throughout the lower Columbia River, and lumber loaded aboard schooners was bound for California. As markets and technology for wood removal expanded, timber operations spread throughout the region. In 1911, 100 years after the initial settlement in Astoria, the state legislature enacted a law creating a state forestry department and appointed a state forester. The main interest at this time was fire protection as harvest practices and continual land clearing were threatening what was now deemed a valuable forest resource.

Even with this new-found interest in fire protection, human-caused, large forest stand-replacement fires burned through a large portion of this region in 1933, 1939, 1945 and 1951, leaving a large non-forested area referred to as the Tillamook Burn. The origin of the fires was ignition by logging equipment, and fires were fueled by large amounts of logging debris and dry winds. Adjacent standing forests also burned, with a cumulative total of over 140,000 ha of forest affected during those years. Reforestation on these sites was severely limited by lack of seed trees and by use of the newly established shrublands and grasslands for cattle grazing. These sites remained largely

non-forested until the mid-1950's when a massive reforestation effort was undertaken using aerial seeding and hand-planting techniques. Successful reforestation efforts on the Tillamook Burn – now the Tillamook State Forest – soon led to replanting of vast areas, previously logged and/or burned as well as abandoned farmland and pasture.

The cumulative effects of land clearing, timber harvest techniques and fire combined with ecosystem responses and forest planting and management to create the forests that currently blanket this region. For example, early forest harvesting objectives were to remove only merchantable tree species in the vicinity of major waterways. Logging focused on large diameter, knot-free logs leaving the remainder as slash on the site. In the absence of fire, the forests that resulted from these slash-filled, selective "cut and run" harvest techniques favored the more shade-tolerant western hemlock, cedar, and Sitka spruce. Douglas-fir was not well regenerated even following slash fires, probably because often the fires were very intense, large and at frequent intervals, eliminating adequate seed sources.

The region's economic infrastructure reflected the changes in land uses. Capital investments in transportation and wood processing made the region a major focus of economic activity. The creation of employment led to the immigration of a work force not only from across the United States, but from overseas as well. The social-cultural, as well as economic structure and character of Northwestern Oregon was a direct product of the region's natural resource base; at the same, these human qualities began to lead to changes that would inevitably be reflected in the region's natural resources and the policies and programs governing their management.

In the 20th century, the socio-cultural and economic structure of northwest Oregon began to change. To the east, the city of Portland grew rapidly, and its economic base was highly diversified. It served as a focal point for the transportation of goods from the hinterland to the south through the Willamette Valley and by ship to California and beyond, in addition to being an important trans-shipment point for goods and products from eastern Oregon. With economic growth came an expanded demand for a host of other activities in the manufacturing, service, and industrial sectors. As Portland's economic presence grew, so too did the demand for an expanded workforce. In the middle decades of this century, Washington County, on the eastern edge of our four-county region, increasingly became a "bedroom community" to the Portland area with simultaneous losses of agricultural and forest lands. For example, the Washington County population grew 12-fold between 1930 and 1994 (and in fact, doubled between 1970 and 1994); during this same period, the population of the remaining three counties has approximately doubled. In addition, while Clatsop, Columbia, and Tillamook counties today remain

close to the rural-urban distribution reported in the 1950 Census (53, 21, and 20 percent urban, respectively), Washington County's urban population shifted from 31% in 1950 to 90% in 1990.

The dramatic change in the amount and distribution of population in the four-county region was matched by an equally impressive shift in the proportion of persons employed in various sectors. In the 20-year period from 1972–1992, the number of persons employed in the lumber and wood products industries fell, on average, more than half in all four counties; in Tillamook, it dropped from 38% of the total workforce to 9%. It is also worth noting that Federal forest ownership in the four-county region is low; the shift in employment reflects the wood product industry restructuring and the adoption of new, more efficient technologies more than it does reductions in supply of timber from federal lands in this region (this is not necessarily the case for other areas of Oregon).

In the western two-thirds of this landscape, the early land clearing is no longer readily apparent, particularly where climate restricted modern agriculture. Once abandoned, the agricultural lands were rapidly colonized by forest ecosystems, and today the only indication of clearing is an occasional apple tree, daffodil flower and a noticeable lack of tree stumps. In the eastern part of the landscape, bordering the Willamette Valley, agricultural crops were much more productive and the bottom lands remain largely agricultural except where replaced by urban development. In general, the percentage of land that has remained forested is much higher in the western counties where the value of the land for timber production is higher than for other uses. In the eastern counties, on a fringe of a major city, there are many more options for financial return from the land such as housing, agriculture and commercial development.

The major impact of recent European settlement has been to restart the successional clock on more frequent intervals. Currently, there is only a small remnant of forests that existed prior to the 1800's and a majority of the forested area has been through two or three harvest/fire cycles in the past 170 years. In the coastal regions, the forests that seeded in following the initial logging and fires are primarily later successional species such as western hemlock, cedar and Sitka spruce. The current stocking in these stands is generally very high, and the stands are just entering a phase where competition and wind-caused mortality reduce stem densities thereby prompting timber harvest

Today, in accordance with biophysical and socio-cultural forces, Northwest Oregon has a variety of forest types: 1) western hemlock, Sitka spruce, red alder and Douglas-fir forests that seeded in naturally following selective timber harvests in the early-mid 1900s; 2) dense Douglas-fir forests that were

planted and seeded following stand replacement fires in the early-mid 1900s; 3) young stands of Douglas-fir recently planted following harvest and now sharing their growing space with naturally regenerating spruce, hemlock and red alder; 4) forests which either invaded or were deliberately planted on land originally cleared for agriculture.

The pattern of and relative abundance of the mosaic of planted and naturally regenerated forests are dispersed throughout the landscape, and their relative abundance is directly tied to the land use practices following European settlement. Human interaction is currently responsible for the relatively young age class of both the planted and natural forests throughout this region.

Human influences on forest structure-the future

In short, what this brief overview reveals is a region in transition. It is a transition not unlike that found in other regions, not only in the Pacific Northwest, but indeed, around the world. It is a transition driven by complex, interwoven forces. Changes in public attitudes, shifts in technology, changing markets, and so forth have led to profoundly different ways in which resources are valued, perceived, and managed. The resulting changes are painful, especially for those whose livelihood is tied to a way of life and a means of sustaining themselves that finds itself in decline. Yet our capacity to respond to change reflects our only ability to meet the future

In the future, the types of forests that occur across this landscape will be shaped by the decisions and policies in accordance with fluxes in biophysical forces. The interaction of these factors has shaped the forests ecosystems we are currently managing and their imprint will remain across the landscape coupled with new and evolving forces. The rate at which change is occurring will probably have the largest impact. Using a geological reference, fluxes in climate and rates and intensity of disturbances influencing forest composition were likely very different from current rate of change, and ecosystem responses will result in additional widespread changes in the shifting mosaic of forests across the landscape.

As we move through time, the percentage of forests regenerated from seed following harvest or other disturbance will probably decline. Increased value of timber products, as well as land costs, and concerns about soil erosion will encourage landowners to invest in the rapid reforestation of their harvested lands through planting. The cycle of harvest and abandonment that produced so many of the forests across our current landscape are a product of the past “pioneering” mentality. Lessons learned from transferring seedlings out of the

region to which they are locally adapted will result in more careful guidelines for matching seedling origin to site characteristics.

Afforestation will continue to take place, particularly as agriculture aggregates in the more productive locations. Agricultural production across much of this landscape is in decline because increasing land values, urbanization pressures, and cost to market are resulting in shifting economic opportunities. In the western end of this region farmers and ranchers are continuing to look at alternative crops such as hybrid poplar. In many of the lowlands marginal for dairy and pasture, production will likely shift to high yield poplar plantations to be managed much like a farm crop.

The biophysical response of the forest ecosystems to current management practices will shape many of our future forest types and hence management options. The historic and current timber harvests across this landscape have perpetuated young forests – the majority now younger than 80 yrs. Looking back several thousand years, this shift toward early successional age classes is not unusual in this landscape. However, there are ecosystem impacts already observed with keeping stands in early successional stages over several rotations. One example of this is the Sitka spruce tip weevil. The weevil infects young spruce under 18 meters tall resulting in dead terminal leaders and stunted height growth (Furniss and Carolin 1977). Studies have shown that this beetle is not highly migratory and spread of infection can be very slow, particularly if there are no susceptible spruce to move to (Wright 1960; McMullen et al. 1987). However in our current landscape with a large percentage of the spruce in the susceptible age-class the weevil has become so prevalent that the western hemlock and Douglas-fir are outcompeting the now stunted Sitka spruce trees. Although far from being eliminated across its native range, Sitka spruce will provide constrained future management options limited by poor growth and shifting markets.

As our colleague silviculturist John Tappeiner points out (personal communication), planted forests of Douglas-fir in this region are “versatile” and resilient, can be very long-lived – to more than 500 years, and can continue to produce impressive wood growth at old ages. Rotation ages for wood production of 100 years are not unreasonable, and could be extended to 150 years or more if desired for management objectives. Rapid growth can produce trees of 1.5–2 m in diameter at age 120 to 150 years. (Of course, individual trees can live to 300 to 400 years age.) During long-rotation cycles relatively frequent thinnings and stand tending for wood production would be possible and desirable. Douglas-fir planted forests can be managed in any of a variety of ways: for industrial wood production at relatively high densities for relatively short (40–80 years) rotations; at lower stand densities and for longer rotations, e.g. to 150 years, to provide large trees and old forest

characteristics; in combinations of these or other scenarios. Individual stands can be grown for wood production for about 50 years, then repeatedly thinned and shifted to development of old forests. This seems to be the path that some public land management organizations are curently following.

In a landscape so obviously dominated by forested ecosystems the origins and age class distributions of the forests will have a significant effect on the total region. The mosaic of forest types across this landscape is currently a product of complex and rapidly changing bio-physical and social forces linked with policies and economics. One of the fundamental questions that has not been addressed in this descriptive narrative is whether the origins of the forests are as important as their potential contributions to desired near- and distant-future landscape conditions. If the landscape in question is seen as an integration of forests and humans, then the desired landscape condition will include features which are present to benefit just the forests, features which are beneficial to the humans, and features which are mutually beneficial. Future conditions of forests, regardless of origin, should be designed with multiple values in mind, with continually evolving forest management practices and monitoring. Forests of northwestern Oregon have the potentials and resilience to provide myriad human values and can be managed to preserve many options for the future.

The challenge of sustainability

Our purpose in this brief review of northwest Oregon has been to use it as illustrative of both the circumstances and history of many formerly timber-dependent areas as well as to help frame the kinds of challenges facing such regions in the future. To conclude, we address five key issues confronting policymakers, citizens, and members of the forestry profession. Using the framework of biophysical forces in accordance with human influence outlined in this paper to stimulate thinking, we challenge readers to review these key issues with an appreciation for the complexity and potential variety of solutions associated with them. First, growing public interest in the concept of sustainability has resulted in increasing attention given to the questions of both resource production and consumption. Such interest is welcome because such discussions are critical to identifying appropriate choices for the future. However, we need to be cautious in our optimism. Sustainability is, in many ways, an excellent example of the concept of a “guiding fiction”; i.e., images and constructs that serve to provide a sense of identity, community, and purpose at any abstract level, but, like the end of the rainbow, fade as we attempt to define and clarify them (Shumway 1991). As rhetoric, sustainability has had the desirable effect of encouraging discussions about issues

of common concern; e.g., our future, the relationship with the environment. However, such discussions often fail to come to grips with the extraordinarily complex and difficult social choices that a sustainable future will necessarily demand. Questions of what should be sustained (Gale and Cordray 1991), for whom, through what means, and over what spatial and time scales (Stankey 1995) must be resolved before sustainability can become more than rhetoric.

Second, resolving a complex issue such as sustainability is further confounded by the growing separation of production and consumption typically found in modern industrialized societies. Today, more than eight out of ten Americans reside in urban areas (similar figures can be found in other industrialized societies). The resulting "disconnection" between a population that demands and consumes a variety of goods and services and the resources and resource management activities that make that demand and consumption possible raises difficult questions about the capacity of society to make informed choices, given that such choices lead to consequences that are often only poorly identified, let alone understood. Given that population projections generally foresee a continuation of the urbanization of the country, it is clear that major challenges confront the natural resource professions in helping the wider society understand the implications and consequences of choices relative to natural resource management.

This leads to the third challenge. Political scientists speak of the "quandary" facing modern societies: i.e., "how can the democratic ideal of public control be made consistent with the realities of a society dominated by technically complex policy questions?" (Pierce and Lovrich 1983, p. 1). That is, most western industrialized societies rely upon a democratic form of government; political power is vested in the citizenry. However, an increasingly complex world confronts such societies with a major challenge; how to retain democratic traditions and processes while, at the same time, making informed, intelligent decisions about technically complex questions. Do we simply turn the major prescriptive questions before society over to the "experts" (e.g., foresters, engineers, physicians)? It is tempting to simply call for more education and while this clearly is important, such a response probably oversimplifies the issue. Foresters and other natural resource specialists have been, and will continue to be, challenged by such questions, and innovative approaches to engaging the wider society in discussions about the future of our forests are sorely needed.

Fourth, there is mounting evidence of the need for new institutional structures to manage natural resources in an increasingly complex future and in response to growing demands and societal preferences. The inadequacy of current institutions has drawn increasing attention. For example, most commentators on the emerging notion of "ecosystem management" point

to the inability of current institutions to contend effectively and appropriately with what would appear to be the central tenets of such a management approach (e.g., Grumbine 1994; Freemuth 1996). This would include the need to manage across long-time scales, over large, multi-jurisdictional spatial scales, and for a wide range of values. However, institutions often possess powerful inertia (Wilkinson 1992); changing the variety of formal and informal organizations, behaviors, and norms that govern forest management today will likely encounter strong resistance from many quarters.

Finally, it is clear we face major challenges to integrating planted forests, natural forests, and society. Despite the growing interest in integrated resource management, it, like sustainability, remains more in the realm of rhetoric than reality. Many reasons underlie this, not the least of which is simply that thinking and behaving in an integrated fashion (i.e., an inclusive, holistic manner) is extremely difficult, given the complexity of the systems with which we are involved and our inadequate understanding of second- and third-order effects. However, more subtle, yet formidable barriers also limit our ability to manage on an integrated basis. Functionally-based budgeting systems and disciplinary-bounded organizations, for example, operate to differentiate rather than synthesize. Yet, the kinds of issues and pressures that will surely characterize future forest management will make an integrative approach to management necessary. Resource professionals, including those in the academic institutions, will be challenged to promote innovative processes and structures to better achieve true integration.

The region of northwestern Oregon, our backyard, will be one of many testing grounds for responses to these challenges. The process is intense and contentious as we write, with uncertainty as to whether timber production should be explicitly stated as the primary goal for certain state lands which are mandated to be managed for the “benefit” of the residents of the counties. That issue may soon be “resolved” by a decision, but the debates and forest management challenges will long continue as the landscape evolves in response to biophysical, social, economic and political forces, acting in this, another El Niño year, and beyond.

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